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(54) **TISSUE ABLATION SYSTEM WITH ENERGY DISTRIBUTION**

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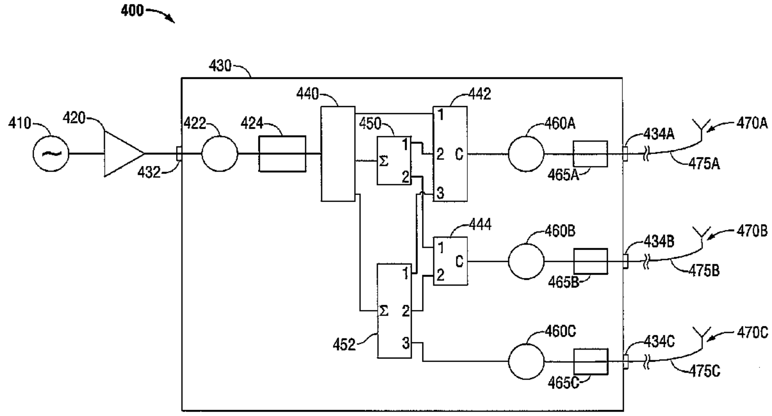
(57) **ABSTRACT**

A microwave ablation system includes an energy source adapted to generate microwave energy and a power splitting device having an input adapted to connect to the energy source and a plurality of outputs. The plurality of outputs are configured to be coupled to a corresponding plurality of energy delivery devices. The power splitting device is configured to selectively divide energy provided from the energy source between the plurality of energy devices.

14 Claims, 4 Drawing Sheets



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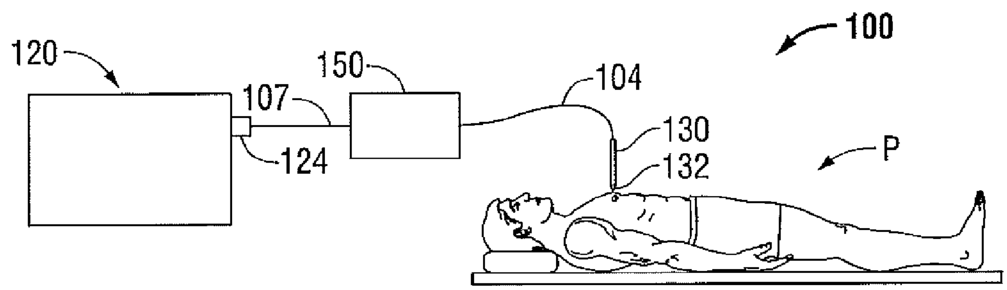
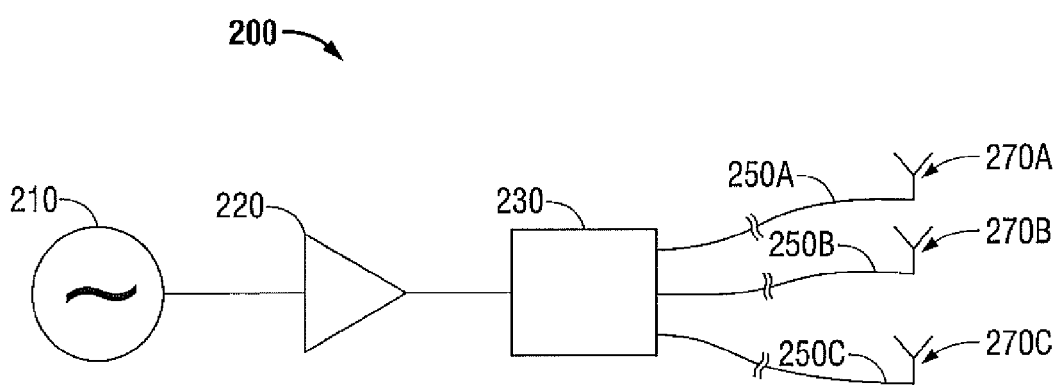

100
120
150
104
107
130
132
124
P

FIG. 1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210
220
230
250A
250B
250C
270A
270B
270C

FIG. 2

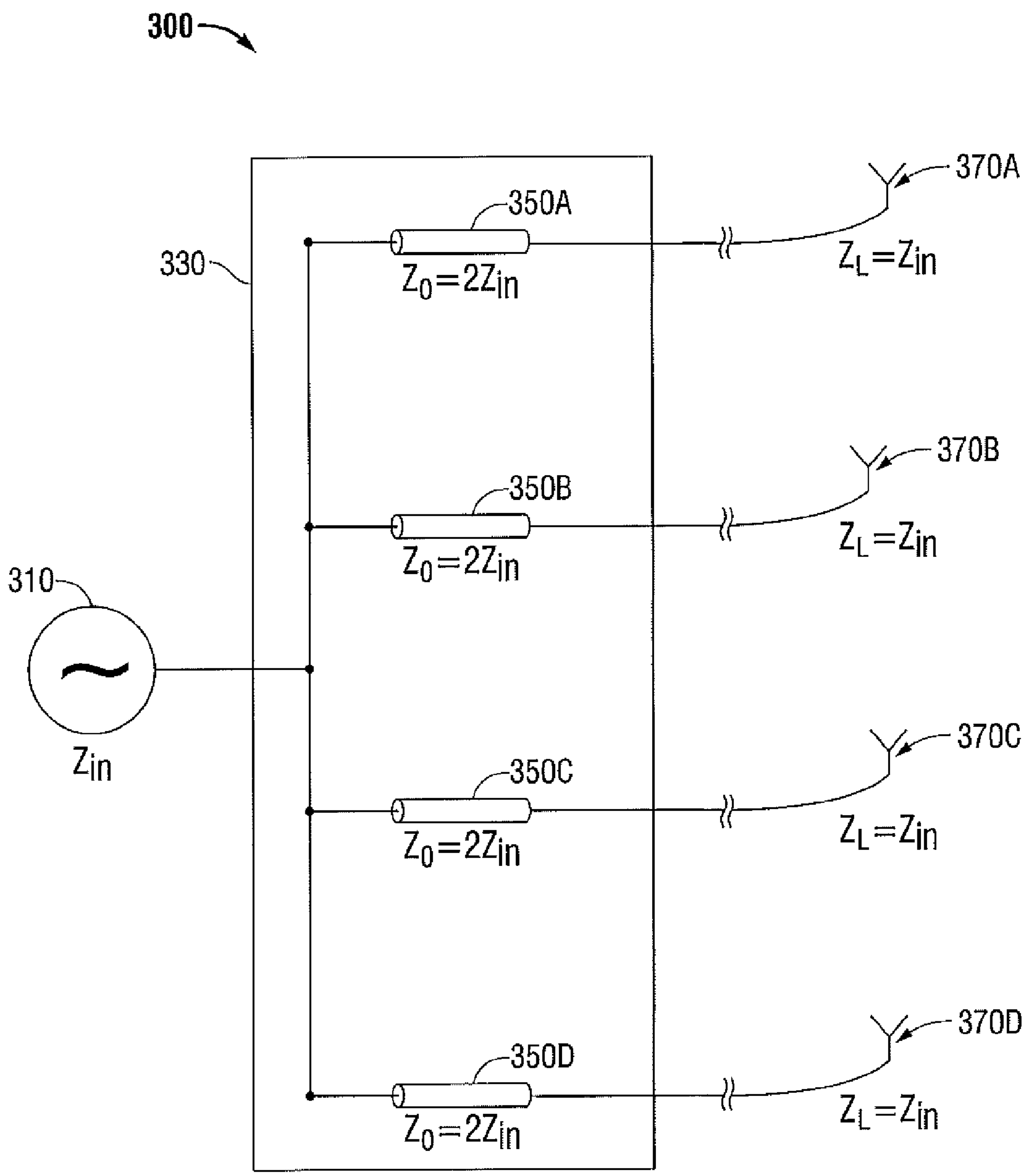
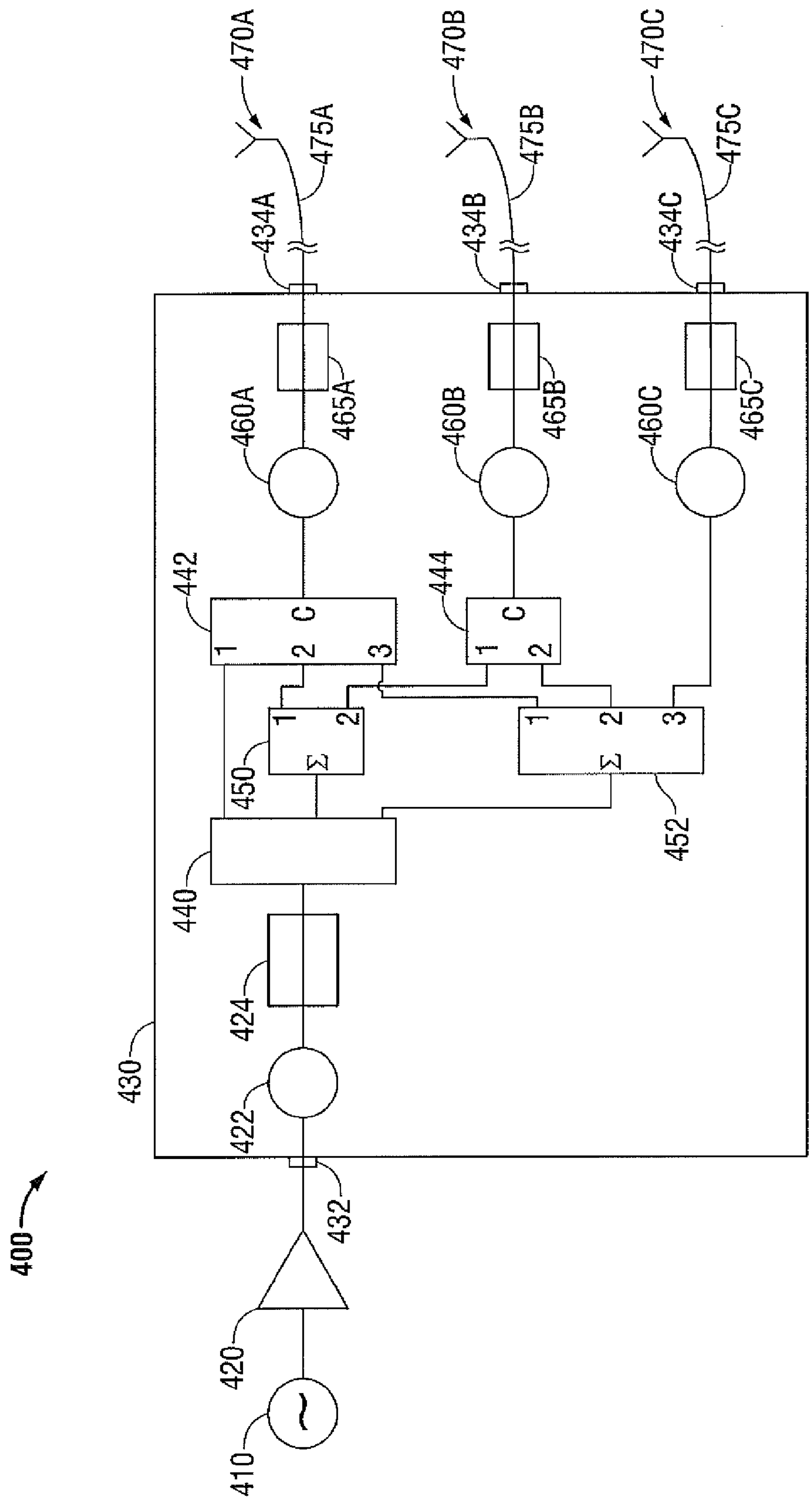

300
330
310
Zin
350A
350B
350C
350D
Z0=2Zin
Z0=2Zin
Z0=2Zin
Z0=2Zin
370A
370B
370C
370D
ZL=Zin
ZL=Zin
ZL=Zin
ZL=Zin

FIG. 3



400
410
420
432
422
430
424
440
450
452
442
444
1
2
3
C
Σ
460A
460B
460C
465A
465B
465C
434A
434B
434C
475A
475B
475C
470A
470B
470C

FIG. 4

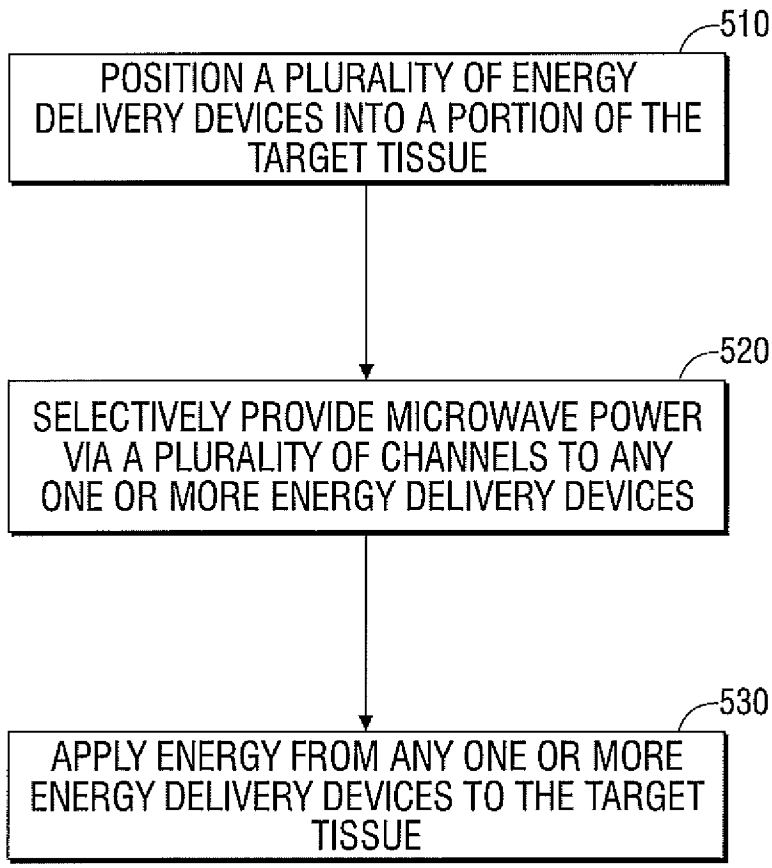

510
POSITION A PLURALITY OF ENERGY DELIVERY DEVICES INTO A PORTION OF THE TARGET TISSUE
520
SELECTIVELY PROVIDE MICROWAVE POWER VIA A PLURALITY OF CHANNELS TO ANY ONE OR MORE ENERGY DELIVERY DEVICES
530
APPLY ENERGY FROM ANY ONE OR MORE ENERGY DELIVERY DEVICES TO THE TARGET TISSUE

FIG. 5

TISSUE ABLATION SYSTEM WITH ENERGY DISTRIBUTION

BACKGROUND

1. Technical Field

The present disclosure relates to apparatus and methods for providing energy to tissue and, more particularly, to devices and electromagnetic radiation delivery procedures utilizing ablation probes and methods of controlling the delivery of electromagnetic radiation to tissue.

2. Discussion of Related Art

Treatment of certain diseases requires destruction of malignant tumors. Electromagnetic radiation can be used to heat and destroy tumor cells. Treatment may involve inserting ablation probes into tissues where cancerous tumors have been identified. Once the probes are positioned, electromagnetic energy is passed through the probes into surrounding tissue.

In the treatment of diseases such as cancer, certain types of cancer cells have been found to denature at elevated temperatures that are slightly lower than temperatures normally injurious to healthy cells. Known treatment methods, such as hyperthermia therapy, use electromagnetic radiation to heat diseased cells to temperatures above 41° C. while maintaining adjacent healthy cells below the temperature at which irreversible cell destruction occurs. These methods involve applying electromagnetic radiation to heat, ablate and/or coagulate tissue. Microwave energy is sometimes utilized to perform these methods. Other procedures utilizing electromagnetic radiation to heat tissue also include coagulation, cutting and/or ablation of tissue.

Electrosurgical devices utilizing electromagnetic radiation have been developed for a variety of uses and applications. A number of devices are available that can be used to provide high bursts of energy for short periods of time to achieve cutting and coagulative effects on various tissues. There are a number of different types of apparatus that can be used to perform ablation procedures. Typically, microwave apparatus for use in ablation procedures include a microwave generator, which functions as an energy source, and a microwave surgical instrument having an antenna assembly for directing the energy to the target tissue. The microwave generator and surgical instrument are typically operatively coupled by a cable assembly having a plurality of conductors for transmitting microwave energy from the generator to the instrument, and for communicating control, feedback and identification signals between the instrument and the generator.

Microwave energy is typically applied via antenna assemblies that can penetrate tissue. Several types of antenna assemblies are known, such as monopole and dipole antenna assemblies. In monopole and dipole antenna assemblies, microwave energy generally radiates perpendicularly away from the axis of the conductor. A monopole antenna assembly includes a single, elongated conductor that transmits microwave energy. A typical dipole antenna assembly has two elongated conductors, which are linearly aligned and positioned end-to-end relative to one another with an electrical insulator placed therebetween. Each conductor may be about ¼ of the length of a wavelength of the microwave energy, making the aggregate length of the two conductors about ½ of the wavelength of the supplied microwave energy. During certain procedures, it can be difficult to assess the extent to which the microwave energy will radiate into the surrounding tissue, making it difficult to determine the area or volume of surrounding tissue that will be ablated.

SUMMARY

According to an embodiment of the present disclosure, a microwave ablation system includes an energy source adapted to generate microwave energy and a power splitting device having an input adapted to connect to the energy source and a plurality of outputs. The plurality of outputs are configured to be coupled to a corresponding plurality of energy delivery devices. The power splitting device is configured to selectively divide energy provided from the energy source between the plurality of energy devices.

According to another embodiment of the present disclosure, a microwave ablation system includes an energy source adapted to generate microwave energy and a power splitting device having an input adapted to connect to the energy source and a plurality of outputs. The plurality of outputs are configured to be coupled to a corresponding plurality of energy delivery devices via corresponding transmission lines. The power splitting device is configured to selectively divide energy provided from the energy source between the plurality of energy delivery devices either equally or unequally.

According to another embodiment of the present disclosure, a method for providing energy to a target tissue includes the steps of positioning a plurality of energy delivery devices into a portion of the target tissue and selectively dividing energy on a plurality of channels to at least one of the energy delivery devices. The method also includes applying energy from one or more of the energy delivery devices to the target tissue.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic diagram of an electrosurgical system for treating tissue, according to an embodiment of the present disclosure;

FIG. **2** is a schematic diagram of an electrosurgical system for treating tissue, according to one embodiment of the present disclosure;

FIG. **3** is a schematic diagram of an electrosurgical system for treating tissue, according to another embodiment of the present disclosure;

FIG. **4** is a schematic diagram of an electrosurgical system for treating tissue, according to another embodiment of the present disclosure; and

FIG. **5** is a block diagram illustrating a method for treating tissue, according to an embodiment of the present disclosure.

DETAILED DESCRIPTION

Hereinafter, embodiments of the presently disclosed tissue ablation systems are described with reference to the accompanying drawings. Like reference numerals may refer to similar or identical elements throughout the description of the figures. As used herein, the term “microwave” generally refers to electromagnetic waves in the frequency range of 300 megahertz (MHz) (3×108 cycles/second) to 300 gigahertz (GHz) (3×10" cycles/second). As used herein, the phrase “transmission line” generally refers to any transmission medium that can be used for the propagation of signals from one point to another (including, but not limited to coaxial cables, waveguides etc.).

Various embodiments of the present disclosure provide electrosurgical systems for treating tissue and methods of controlling the delivery of electromagnetic radiation to tissue.

Embodiments may be implemented using electromagnetic radiation at microwave frequencies or at other frequencies. Electrosurgical systems for treating tissue, according to various embodiments of the present disclosure, deliver microwave power to a plurality of electrosurgical devices. Electrosurgical devices, such as ablation probes, for implementing embodiments of the present disclosure may be inserted directly into tissue, inserted through a lumen, such as a vein, needle or catheter, placed into the body during surgery by a clinician, or positioned in or on the body by other suitable methods known in the art.

FIG. **1** is a schematic diagram of an electrosurgical system for treating tissue, according to one embodiment of the present disclosure. Referring to FIG. **1**, the electrosurgical system **100** includes an electrosurgical generator **120** for generating an output signal, a power splitter **150** coupled to the electrosurgical generator **120**, and an electrosurgical instrument or device **130** coupled to the power splitter **150**. The power splitter **150** is coupled to a transmission line **107** that electrically connects the power splitter **150** to an output **124** on the electrosurgical generator **120**. The device **130** includes an antenna assembly **132** for delivery of electromagnetic radiation, coupled to a transmission line **104** that electrically connects the antenna assembly **132** to the power splitter **150**. Although not shown as such in FIG. **1**, device **130** may include a plurality of antenna assemblies.

The electrosurgical generator **120** may include other input or output devices such as knobs, dials, switches, buttons, graphical user interfaces, displays, and the like for control, indication and/or operation. The electrosurgical generator **120** may be capable of generating a plurality of output signals of various frequencies that are input to the power splitter **150**. In one embodiment, the electrosurgical generator **120** generates a plurality of microwave signals at substantially the same frequency. The electrosurgical generator **120** may include a control unit (not shown) that controls operations of the electrosurgical generator **120**, such as time of operation, power output and/or the mode of electrosurgical operation, which may have been selected by the clinician.

The electrosurgical system **100** may include a footswitch (not shown) coupled to the electrosurgical generator **120**. When actuated, the footswitch causes the electrosurgical generator **120** to generate microwave energy. The device **130** may include knobs, dials, switches, buttons or the like (not shown) to communicate to the electrosurgical generator **120** to adjust or select from a number of configuration options for delivering energy. Utilizing knobs, dials, switches or buttons on the device **130** and/or a footswitch enables the clinician to activate the electrosurgical generator **120** to energize the device **130** while remaining near the patient P regardless of the location of the electrosurgical generator **120**.

Although not shown as such in FIG. **1**, electrosurgical system **100** may include a plurality of channels defined by a plurality of electrosurgical devices and a plurality of transmission lines that electrically connect the electrosurgical devices to the power splitter **150**. In an embodiment, the power splitter **150** is capable of monitoring the phase of each channel and adjusting the phase of the signal in each channel with respect to the other channel(s) to a predetermined phase relationship. The power splitter **150** provides a plurality of signals to the device **130** in a set of phase relationships between the signals. Although the power splitter **150** is illustrated as a standalone module in FIG. **1**, it is to be understood that the power splitter **150** may be integrated fully or partially into the electrosurgical generator **120**, the device **130**, and/or other devices. Furthermore, it may be appreciated that electrosurgical generator **120**, output **124**, transmission lines **107** and **104** and power splitter **150** could be integrated within device **130**, thus obviating the need for separate elements.

The antenna assembly **132** includes multiple antennas and/or multiple antenna elements, each driven by an output signal of the power splitter **150**. The antenna assembly **132** may also include multiple antenna circuits, each driven by an output signal of the power splitter **150**.

In embodiments, the antenna assembly **132** is a microwave antenna configured to allow direct insertion or penetration into tissue of the patient P. The antenna assembly **132** may be axially rigid to allow for tissue penetration. The antenna assembly **132** is sufficiently small in diameter to be minimally invasive of the body, which may reduce the preparation of the patient P as might be required for more invasive penetration of the body. The antenna assembly **132** is inserted directly into tissue, inserted through a lumen, such as, for example, a vein, needle or catheter, placed into the body during surgery by a clinician, or positioned in the body by other suitable methods.

FIG. **2** is a schematic diagram of an electrosurgical system for treating tissue, according to another embodiment of the present disclosure. Referring to FIG. **2**, the electrosurgical system **200** includes a microwave signal source **210** providing a microwave frequency output signal to a microwave amplifier unit **220**, a microwave power splitter **230** coupled to the microwave amplifier unit **220**, and a first, a second and a third microwave ablation antenna assembly **270**A, **270**B and **270**C, each coupled to the microwave power splitter **230**. The microwave signal source **210** is capable of generating a plurality of output signals of various frequencies that are input to the microwave amplifier unit **220**. The microwave amplifier unit **220** may have any suitable input power and output power.

In the electrosurgical system **200**, a first transmission line **250**A electrically connects the first antenna assembly **270**A to the microwave power splitter **230**, defining a first channel; a second transmission line **250**B electrically connects the second antenna assembly **270**B to the microwave power splitter **230**, defining a second channel; and a third transmission line **250**C electrically connects the third antenna assembly **270**C to the microwave power splitter **230**, defining a third channel. The first, second and third transmission lines **250**A, **250**B and **250**C may each include one or more electrically conductive elements, such as electrically conductive wires.

In an embodiment, the first, second, and third transmission lines **250**A, **250**B and **250**C each have substantially the same length, which preserves the phase relationship between the electrical signals in each channel of the electrosurgical system **200**. It is to be understood that "length" may refer to electrical length or physical length. In general, electrical length is an expression of the length of a transmission medium in terms of the wavelength of a signal propagating within the medium. Electrical length is normally expressed in terms of wavelength, radius, or degrees. For example, electrical length may be expressed as a multiple or sub-multiple of the wavelength of an electromagnetic wave or electrical signal propagating within a transmission medium. The wavelength may be expressed in radians or in artificial units of angular measure, such as degrees. The microwave power splitter **230** may be implemented by any suitable power divider that provides equal or unequal power split at the output ports of the microwave power splitter **230** while substantially maintaining phase and amplitude balance. For example, the microwave power splitter **230** may be implemented using a 3-way power divider that provides equal or unequal power split at its output ports while maintaining a phase balance of <+/−45 degrees.

Each antenna assembly **270**A, **270**B and **270**C typically includes a rigid or bendable needle or needle-like structure.

The antenna assemblies **270**A, **270**B and **270**C are positioned substantially parallel to each other, for example, spaced about 5 millimeters (mm) apart, and inserted directly into tissue or placed into the body during surgery by a clinician, or positioned in the body by other suitable methods. Although the electrosurgical system **200** illustrated in FIG. **2** includes three microwave ablation antenna assemblies **270**A, **270**B and **270**C, it is to be understood that any "N" number of antenna assemblies may be utilized and that microwave power splitter **230** may be implemented by any suitable power divider that divides or splits a microwave input signal into "N" number of output signals of equal or unequal power.

The electrosurgical system **200** delivers microwave power to one or more antenna assemblies **270**A, **270**B and **270**C of the three-channel system. The electrosurgical system **200** may deliver substantially in-phase microwave power to each antenna assembly **270**A, **270**B and **270**C. By controlling the phase of ablation probes with respect to each other, according to embodiments of the present disclosure, a desired effect on tissue between the probes is produced. In ablation procedures using in-phase probes, according to various embodiments of the present disclosure, there may be a reduction in energy that might otherwise move between the antenna shafts toward the surface with out-of-phase probes.

In an embodiment, the electrosurgical system **200** is implemented with operating frequencies in the range of about 300 MHz to about 5 GHz, which may be useful in performing ablation procedures and/or other procedures. It is to be understood that the electrosurgical system **200** may be implemented with any appropriate range of operating frequencies.

In another embodiment, the electrosurgical system **200** delivers microwave power to particular channels individually or any combination of one or more channels equally or unequally. The microwave signal source **210** and/or antenna assembly **270**A, **270**B and **270**C may include input or output devices such as knobs, dials, switches, buttons, graphical user interfaces, displays, and the like to facilitate selective activation of energy delivery to particular channels or combination of channels. For example, a user may select channels to which energy is delivered. In this scenario, if the second and third channels are selected, energy delivery may be divided equally (e.g., P/2) between the second and third channels and, thus, unequally between the first channel and the second and third channels since no energy is delivered to the first channel in this scenario. Further, in this scenario, energy may be delivered to individual channels according to selected time intervals by dynamically changing the channels to which energy is delivered. For example, energy may be delivered to the first channel at a time interval t**1**. At a subsequent time interval t**2**, energy is delivered to the first channel and the third channel. At a subsequent time interval t**3**, energy delivery to the first channel is stopped and energy delivery to the third channel continues. At a subsequent time interval t**4**, energy delivery to all channels is stopped.

In another embodiment, the microwave power splitter **230** divides energy between the antenna assemblies **270**A, **270**B and **270**C to tailor the size and shape of ablation lesions. With this purpose in mind, electrosurgical system **200** may include a suitable storage device (not shown) integrated within the microwave signal source **210**, the microwave power splitter **230**, or be a stand-alone device, that is configured to store settings or data corresponding to particular ablation geometries (e.g., ablation images, antenna tip geometries, power division settings, power amplitude settings, etc.). Based on the stored settings or data, the microwave signal source **210** modifies delivery of microwave power to the microwave power splitter **230** and/or the microwave power splitter **230** modifies the division of microwave power between the channels to achieve the desired ablation geometry.

FIG. **3** is a schematic diagram of an electrosurgical system for treating tissue, according to an embodiment of the present disclosure. Referring to FIG. **3**, the electrosurgical system **300** includes a microwave signal source **310** providing a microwave frequency output signal to a microwave power splitter **330**, and a first, a second, a third, and a fourth microwave ablation antenna assembly **370**A, **370**B, **370**C, and **370**C, each coupled to the microwave power splitter **330**. The microwave signal source **310** is capable of generating a plurality of output signals of various frequencies that are input to the microwave power splitter **330**.

The microwave power splitter **330** includes a first quarter wavelength transmission line **350**A that electrically connects the first antenna assembly **370**A to the microwave signal source **310**, defining a first channel; a second quarter wavelength transmission line **350**B that electrically connects the second antenna assembly **370**B to the microwave signal source **310**, defining a second channel; a third quarter wavelength transmission line **350**C that electrically connects the third antenna assembly **370**C to the microwave signal source **310**, defining a third channel; and a fourth transmission line **350**D that electrically connects the fourth antenna assembly **370**D to the microwave signal source **310**, defining a fourth channel. Transmission lines **350**A, **350**B, **350**C, and **350**D each include one or more electrically conductive elements, such as electrically conductive wires. In an embodiment, transmission lines **350**A, **350**B, **350**C, and **350**D each have substantially the same length, which preserves the phase relationship between electrical signals in each channel of the electrosurgical system **300**.

As is known in the art, for maximum power transfer between a power source (e.g., microwave signal source **310**) and a load (e.g., antenna assemblies **370**A, **370**B, **370**C, **370**D), the load impedance must be equal to the source impedance. For the case wherein the transmission line between the power source and the load is quarter wavelength, as described with reference to the embodiment of FIG. **3**, an impedance of the microwave signal source **310** is calculated using the following equation (1):

$$Z_{in}=Z_o^2/Z_L \tag{1}$$

In equation (1), Z_{in} is the input impedance to the quarter wavelength transmission lines **350**A, **350**B, **350**C, and **350**D (e.g., the impedance at the microwave signal generator **310**), Z_o is the characteristic impedance of the quarter wavelength transmission lines **350**A, **350**B, **350**C, and **350**D (e.g., the impedance at the microwave power splitter **330**), and Z_L is the impedance of the antenna assemblies **370**A, **370**B, **370**C, **370**D. Applying equation (1) to the illustrated embodiment of FIG. **3**, yields the following equation (2) to account for the four inputs to the quarter wavelength transmission lines **350**A, **350**B, **350**C, and **350**D:

$$4*Z_{in}=Z_o^2/Z_L \tag{2}$$

Since Z_L must equal Z_{in} to achieve maximum power transfer, as discussed hereinabove, solving for the characteristic impedance Z_o of the quarter wavelength transmission line yields the following equation (3):

$$Z_o=2*Z_{in} \tag{3}$$

By way of example, given that $Z_L=Z_{in}=50$ ohms, the characteristic impedance Z_o of the transmission lines **350**A, **350**B, **350**C, and **350**D is equal to 100 ohms, and the electrical length of the transmission lines **350**A, **350**B, **350**C, and **350**D is set to a quarter wavelength, the load impedance Z_L of the antenna assemblies **370**A, **370**B, **370**C, **370**D at the input of the power splitter **330** is transformed from 50 ohms, which corresponds to a full wavelength, to 200 ohms, which corresponds to a quarter wavelength (i.e., 50 ohms/0.25=200 ohms). Since the four antenna assemblies **370**A, **370**B, **370**C, **370**D are in parallel with microwave signal generator **310**, the equivalent resistance Z_L of the antenna assemblies **370**A, **370**B, **370**C, **370**D is equal to 200 ohms divided by four antenna assemblies or 50 ohms. Since Z_{IN}=50 ohms=Z_L, maximum power transfer will occur between microwave signal generator **310** and each of antenna assemblies **370**A, **370**B, **370**C, **370**D.

Although the electrosurgical system **300** illustrated in FIG. **3** includes four microwave ablation antenna assemblies **370**A, **370**B, **370**C, and **370**D and four quarter wavelength transmission lines **350**A, **350**B, **350**C, and **350**D, it is to be understood that any N number of antenna assemblies and any N number of quarter wavelength transmission lines may be utilized.

FIG. **4** is a schematic diagram of an electrosurgical system **400** for treating tissue, according to another embodiment of the present disclosure. Referring to FIG. **4**, the electrosurgical system **400** illustrated is a three-channel system that includes a microwave signal source **410**, a microwave amplifier **420**, a first, a second, and a third microwave ablation antenna assembly **470**A, **470**B, and **470**C, and a controller **430** that includes one input **432** and a first, a second, and a third output **434**A, **434**B, and **448**C.

The electrosurgical system **400** includes a first transmission line **475**A that electrically connects the first antenna assembly **470**A to the first output **434**A, defining a first channel; a second transmission line **475**B that electrically connects the second antenna assembly **470**A to the second output **434**B, defining a second channel; and a third transmission line **475**C that electrically connects the third antenna assembly **470**C to the third output **434**C, defining a third channel. The first, second, and third transmission lines **475**A, **475**B, and **475**C each include one or more electrically conductive elements, such as electrically conductive wires. In an embodiment, the first, second, and third transmission lines **475**A, **475**B, and **475**C each have substantially the same length, which preserves the phase relationship between electrical signals in each channel of the electrosurgical system **400**.

The microwave signal source **410** provides a microwave frequency output signal to the amplifier **420**. The microwave amplifier **420** provides an output signal through an output terminal that is electrically coupled to the input **432** of the controller **430**. Although the amplifier **420** is illustrated as a standalone module in FIG. **4**, it is to be understood that the amplifier **420** may be integrated fully or partially into the controller **430**. Controller **430** includes a first output-side directional coupler **465**A, a second output-side directional coupler **465**B, and a third output-side directional coupler **465**C. Output-side directional couplers **465**A, **465**B, **465**C are configured to measure power at each output **434**A, **434**B, **434**C, respectively, and to transmit a microwave signal, received as input, to antenna assemblies **470**A, **470**B, and **470**C.

The controller **430** includes a first isolator **422** electrically coupled between the input **432** and an input-side directional coupler **424**. The first isolator **422** operates to appear as a fixed matching load to the microwave signal source **410** to prevent detuning thereof due to variations in load impedance caused by, for example, antenna assemblies **470**A, **470**B, and **470**C and/or transmission lines **475**A, **475**B, and **475**C. The first isolator **422** transmits the microwave signal from the amplifier **420** to the input-side directional coupler **424**. The input-side directional coupler **424** measures the microwave signal received from the amplifier **420** as input and transmits the microwave signal to a first switching device **440** electrically coupled thereto. The first switching device **440** transmits the microwave signal to any one or more of a 1:2 power divider **450**, a 1:3 power divider **452**, and/or a second switching device **442**, individually or in any combination thereof.

Upon receiving the microwave signal from switching device **440**, power divider **450** divides the microwave signal as output between the second switching device **442** and a third switching device **444**. Upon receiving the microwave signal from switching device **440**, power divider **452** divides the microwave signal as output between the second switching device **442**, the third switching device **444**, and the third output-side directional coupler **465**C. The third output-side directional coupler **465**C powers antenna assembly **470**C by transmitting the microwave signal received from power divider **452** to the third output **434**C.

Upon receiving the microwave signal from any combination of the first switching device **440**, power divider **450**, and/or power divider **452**, the second switching device **442** transmits the microwave signal to the first output-side directional coupler **465**A. The first output-side directional coupler **465**A powers antenna assembly **470**A by transmitting the microwave signal received from the second switching device **442** to the first output **434**A.

Upon receiving the microwave signal from any combination of power divider **450** and/or **452**, the third switching device **444** transmits the microwave signal to the second output-side directional coupler **465**B. The second output-side directional coupler **465**B powers antenna assembly **470**B by transmitting the microwave signal received from the third switching device **444** to the second output **434**B.

In operation of electrosurgical system **400**, depending on the configuration of switching devices **440**, **442**, and **444**, the output power values corresponding to the three outputs **434**A, **434**B, and **434**C for a given power P will be either P, 0, and 0; P/2, P/2, and 0; or P/3, P/3, and P/3.

Controller **430** further includes a first isolator **460**A electrically coupled between the second switching device **442** and the first output-side directional coupler **465**A; a second isolator **460**B electrically coupled between the third switching device **444** and the second output-side directional coupler **465**B; and a third isolator **460**C electrically coupled between power divider **452** and the third output-side directional coupler **465**C. First, second, and third isolators **460**A, **460**B, and **460**C are configured to appear as a fixed matching load to the microwave signal generator **410** to prevent detuning thereof due to variations in load impedance caused by, for example, antenna assemblies **470**A, **470**B, and **470**C and/or transmission lines **475**A, **475**B, and **475**C.

Switching devices **440**, **442**, **444** may be any suitable switching device configured to output power to a load connected thereto based on more than one inputs such as, for example, a single pole double throw switch (SPDT), a single pole triple throw switch (SP3T), etc.

In embodiments, any one or more of isolator **422** and isolators **460**A, **460**B, **460**C may be a three-port circulator, as is known in the art, having one of its three ports terminated in a fixed matching load to the microwave signal source **410** to effectively operate substantially as described above with reference to isolator **422** and/or isolators **460**A, **460**B, **460**C.

The controller **430** may include one or more phase detectors (not shown) to compare the respective phases of electrical signals inputted through the input **432**. By comparing a reference signal, such as a clock signal, to a feedback signal using a phase detector, phase adjustments may be made based on the comparison of the electrical signals inputted, to set the phase relationship between electrical signals in each channel of the electrosurgical system **400**.

In an embodiment, the controller **440** delivers phase-controlled microwave power through the outputs **434**A, **434**B and **434**C to the antenna assemblies **470**A, **470**B and **470**C, respectively, irrespective of the phase of the electrical signal inputted through the input **432**.

FIG. **5** is a flowchart illustrating a method for providing energy to a target tissue, according to an embodiment of the present disclosure. Referring to FIG. **5**, in step **510**, a plurality of energy delivery devices are positioned into a portion of the target tissue. The energy delivery devices may be implemented using any suitable electrosurgical instruments or devices, such as, for example, the device **130**, according to embodiments of the present disclosure described in connection with FIG. **1**.

The energy delivery devices are positioned into a portion of a target site on the tissue or adjacent to a portion of a target site on the tissue. The energy delivery devices are inserted directly into tissue, inserted through a lumen, such as a vein, needle or catheter, placed into the body during surgery by a clinician or positioned in the body by other suitable methods. The energy delivery devices include any suitable antenna assemblies for the delivery of electromagnetic radiation, such as, for example, the antenna assemblies **270**A, **270**B and **270**C, according to embodiments of the present disclosure described in connection with FIG. **2**.

In step **520**, microwave power is selectively transmitted on a plurality of channels to any one or more of the energy delivery devices. The microwave power may be transmitted to the energy delivery devices from the microwave power splitter **230**, according to embodiments of the present disclosure described in connection with FIG. **2**, the microwave power splitter **330**, according to embodiments of the present disclosure described in connection with FIG. **3**, or the controller **440**, according to embodiments of the present disclosure described in connection with FIG. **4**.

In step **530**, microwave energy from any one or more energy delivery devices is applied to the target tissue.

While several embodiments of the disclosure have been shown in the drawings, it is not intended that the disclosure be limited thereto, as it is intended that the disclosure be as broad in scope as the art will allow and that the specification be read likewise. Therefore, the above description should not be construed as limiting, but merely as exemplifications of particular embodiments. Those skilled in the art will envision other modifications within the scope and spirit of the claims appended hereto.

What is claimed is:

1. A microwave ablation system, comprising: an energy source adapted to generate microwave energy; a first power splitting device and a second power splitting device, each of the first and second power splitting devices having an input adapted to connect to the energy source and a plurality of outputs; and a plurality of energy delivery devices each including an elongated needle structure configured to be inserted directly into tissue, the plurality of energy delivery devices adapted to electrically communicate with the plurality of outputs of at least one of the first or second power splitting devices; wherein the first and second power splitting devices are configured to selectively divide energy provided from the energy source between the plurality of energy delivery devices, the first power splitting device configured to selectively divide energy from the energy source between at least two of the plurality of energy delivery devices, and the second power splitting device configured to selectively divide energy from the energy source between the at least two energy delivery devices and another energy delivery device from the plurality.

2. A microwave ablation system according to claim **1**, wherein energy is selectively divided equally between the plurality of energy delivery devices.

3. A microwave ablation system according to claim **1**, wherein energy is selectively divided unequally between the plurality of energy delivery devices.

4. A microwave ablation system according to claim **1**, wherein energy is selectively divided between the plurality of energy delivery devices based on at least one pre-determined time interval.

5. A microwave ablation system according to claim **1**, wherein energy is selectively divided between the plurality of energy delivery devices based on a desired ablation geometry.

6. A microwave ablation system according to claim **1**, wherein energy from the energy source is provided to the plurality of energy delivery devices via a corresponding plurality of transmission lines.

7. A microwave ablation system according to claim **6**, wherein the plurality of transmission lines are substantially equal in length to each other.

8. A microwave ablation system according to claim **6**, wherein each of the plurality of transmission lines has a length of a quarter wavelength.

9. A microwave ablation system according to claim **1**, further comprising at least one switching device configured to selectively deliver energy from the energy source to at least one of the first or second power splitting devices.

10. A microwave ablation system according to claim **9**, wherein the at least one switching device is one of a single pole double throw switch or a single pole triple throw switch.

11. A microwave ablation system according to claim **1**, further comprising at least one isolator configured to provide a fixed load relative to the energy source.

12. A microwave ablation system according to claim **1**, further comprising at least one directional coupler configured to measure power at the input of each of the first and second power splitting devices and at least one other directional coupler configured to measure power at the plurality of outputs of each of the first and second power splitting devices.

13. A microwave ablation system, comprising: an energy source adapted to generate microwave energy; a first power splitting device and a second power splitting device, each of the first and second power splitting devices having an input adapted to connect to the energy source and a plurality of outputs; and a plurality of energy delivery devices each including an elongated needle structure configured to be inserted directly into tissue, the plurality of energy delivery devices configured to electrically communicate with the plurality of outputs of at least one of the first or second power splitting devices via corresponding transmission lines; wherein the first and second power splitting devices are configured to selectively divide energy provided from the energy source either equally or unequally between the plurality of energy delivery devices, the first power splitting device configured to selectively divide energy from the energy source between at least two of the plurality of energy delivery devices, and the second power splitting device configured to selectively divide energy from the energy source between the at least two energy delivery devices and another energy delivery device from the plurality.

14. A microwave ablation system according to claim **13**, wherein each energy delivery device of the plurality of energy delivery devices is a microwave ablation antenna.

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